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Technical Memorandum

TESTING OF THE TOW MISSILE-CONFIGURED AH-1T HELICOPTER

Daniel G. Cash
Project Engineer

Rotary Wing Aircraft Test Directorate

15 May 1978

8p.

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DEPARTMENT OF THE NAVY
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Navy flight testing of the Tube-Launched, Optically-Tracked, Wire-Guided (TOW) missile on the AH-1T helicopter was conducted during the Navy Service Acceptance Trials in February and March 1977. Twenty-six TOW missiles, along with 2.75 inch rockets and 20mm ammunition, were fired during this evaluation at the Army's Yuma Proving Ground. This technical memorandum deals with the preparation and conduct of the trials.

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PREFACE

This paper was derived from work performed under AIRTASK A510-5104/053-2/7255-00-380, Work Unit A5104L-04, Initial Trials Phase, Service Acceptance Trials of the TOW missile-configured AH-1T helicopter. This paper was prepared for presentation at the 34th Annual National Forum of the American Helicopter Society, Washington, D.C., May 1978.

APPROVED FOR RELEASE

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Testing of the TOW Missile-Configured AH-1T Helicopter

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Abstract

Navy flight testing of the TOW (Tube-Launched Optically-Tracked Wire-Guided) missile on the AH-1T helicopter was conducted during the Navy Service Acceptance Trials in February and March 1977. Twenty-six TOW missiles, along with 2.75 inch rockets and 20 mm ammunition, were fired during this evaluation at the Army's Yuma Proving Ground. This paper will deal with the following:

a. Preparation for the trials:

(1) Test planning, including safety considerations.

(2) Range preparation, including support requirements.

(3) Special instrumentation.

b. Execution of the trials including:

(1) Weapon accuracy determination.

(2) Effects of aircraft launch parameters on weapon performance.

(3) Analysis of data.

c. Conclusions and recommendations.

High-speed onboard cameras, chase aircraft photo coverage, and ground cameras were used to document phenomena such as 20-mm blast severing the guidance wires, blast effects on airframe components, and target impacts showing extraordinary missile accuracy. The project photo coverage was outstanding and recorded some of the best footage of TOW missile performance ever. The paper will be of extreme interest to a broad spectrum of designers, testers, and users of helicopter and ordnance systems.

Introduction

In 1975 the decision was made to provide the U.S. Marine Corps new attack helicopter, the AH-1T, with an anti-armor/heavy-point target attack capability. The system to be utilized was the U.S. Army developed and qualified M65 TOW Missile System (TMS). This system includes a stabilized, optically-magnified, and motion-compensated periscope sight with associated electronics. Additionally, a helmet sight is included to provide rapid target acquisition. When integrated into the helicopter armament system, both the TMS and helmet sights can be utilized with the flexible GTU-4 20-mm flexible turret. A significant amount of testing had previously been accomplished on these systems installed on the AH-1Q and AH-1S helicopters for the U.S. Army and the AH-1J helicopter for Iran. Therefore, a limited technical and operational test program was established on a prototype AH-1T installation and was completed prior to commiting funds for the production TOW missile and Helmet Sight Subsystems (HSS). This evaluation was oriented primarily at the unique shipboard environment and tactics of the U.S. Marine Corps and the integration of the new armament systems with those integral to the basic AH-1T helicopter.

Conduct of Trials

Aircraft flight test programs are divided into four separate phases: planning, execution, data analysis, and reporting results. The first of these, planning, is distinct and normally precedes the actual test by 6 to 18 months, while the remainder are closely integrated in time.

Planning

The planning phase includes a review of all pertinent data from other test programs in order to establish critical test parameters and requirements and to prepare a detailed test plan. In preparing for the test of the TOW missile-configured AH-1T, a significant data base and test experience had to be reviewed. Numerous contractor and government reports existed on the AH-1Q/S/J helicopters which documented scientific studies and actual test results. Reviewing these data identified the following items which had significant impact on safety requirements:

a. TOW missile launch motor blast caused oil canning and structural damage to AH-1T drive shaft cover during contractor structural test.

b. TOW missile launch motor blast caused uncommanded electrical system shutdown and, therefore, termination of guidance which resulted in an unguided missile on range during AH-1J tests.

c. TOW missile guidance wires wrapped around the main rotor shaft and tail rotor control mechanism during AH-1J tests.

d. A large safety area is required for missile firing.

e. Guidance wires are difficult to police after firing.

f. Firing the 20-mm gun on the AH-1J blurred the Telescopic Sight Unit (TSU) image and resulted in the sight and the rounds being fired drifting off target.

g. TOW missile launch motor blast opened the tail boom electronics access door on the AH-1J.

h. The HSS linkage assembly separated from the helmet during gunfiring, spraying bullets over a large range area during AH-1Q tests.

i. A TMS failure which occurred during TSU/gunfiring resulted in bullets impacting directly below and in front of the AH-1Q.

With knowledge of these facts, critical test program support requirements were established as follows:

a. A land range must be utilized so that an immediate landing could be executed in event of incident.

b. Test personnel must be familiar with the failure modes and effects of the peculiar systems under test.

c. Removal of the TOW missile guidance wires from the range area must not be required.

d. The firing range must have adequate size for TOW missile firing and be available on a full-time basis, including nights.

e. Onboard cameras must include a view of the tail boom and of the missile translating down range to document effects of missile blast.

To meet the critical safety and technical specification requirements, the U.S. Army's Yuma Proving Ground range was chosen for the test program.

Aircraft instrumentation included an extensive array of high-speed photographic cameras for detailed data analysis; video TV (recorded and telemetered) for real-time, quick-look data; aircraft recorded magnetic tape of TOW missile and timing parameters along with cockpit communications; and a transponder for the Yuma Proving Ground position location system. Additional laboratory equipment and cameras, including one located in a chase aircraft, were utilized as necessary to document test results.

<u>Execution, Data Analysis, and Reporting Results</u>

The team assembled to conduct this test effort consisted of military officers and enlisted men, civil service engineers and technicians, and contractor technical representatives. The following is a summary of the results obtained for each subsystem and/or technical specialty.

<u>TOW Missile System</u>

The M65 TMS provides the capability for launching and guiding the TOW anti-armor/heavy-point target missile. It has five functional elements: stabilized telescopic sight, controls and displays, infrared sensors, missile command amplifier, and TOW launchers. These functional elements consist of the Line Replaceable Units (LRU's) identified in figure 1.

The operational procedure is as follows:

a. The gunner acquires and tracks targets with the TSU.

b. The pilot aligns the aircraft with the TSU Line Of Sight (LOS) utilizing the Pilot's Steering Indicator (PSI).

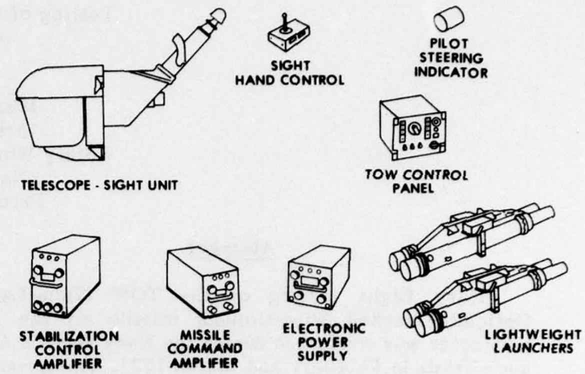


Figure 1
Line Replaceable Units

c. The gunner fires the missile which is captured by the guidance system, as shown in figure 2, and is automatically guided along the gunner's LOS to the target.

d. The pilot is free to maneuver the aircraft after capture of the missile by the guidance system.

TOW LAUNCH AND CAPTURE GEOMETRY

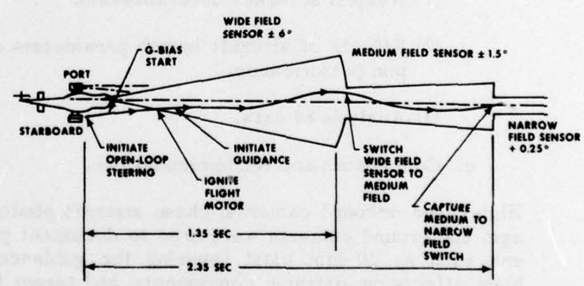


Figure 2
TOW Launch and Capture Constraints

The TMS evaluation included ground and flight tests. Ground tests verified proper subsystem operation, functioning of both pilot and gunner controls, azimuth and elevation limits of the TSU, Built-In Test (BIT) sequencing, steering commands to the 20-mm flexible turret in the TSU/gun mode, operation of the TSU flags and PSI indicators, and functioning of gun camera provisions.

Prior to conducting firing tests, pilot and gunner training exercises were conducted utilizing a Gunner Accuracy Control Panel (GACP). With the GACP installed, all controls were functional and simulated firing passes were executed. During this simulated firing run, the GACP placed a quantitative score on the ability of the gunner to track the target in both the azimuth and elevation and displayed this score on a digital display. Each copilot/gunner practiced with the GACP prior to actual flight firing to ensure familiarity with the system and ensure an adequate confidence level.

Actual firing tests included firing 26 TOW missiles, all equipped with active launch and flight motors and inert warheads. Missile launch conditions, postlaunch maneuvers, and targets are presented in table I.

Table I

Launch conditions	Hover. Straight and level flight to 133 kt (68 m/s). Dives up to 20 deg.
Launch altitudes	0 to 2,721 ft (829 m).
Postlaunch maneuvers	Sustain launch condition. Accelerate at military power. Decelerate, including quick stop. Climb at military power. Left veer off. Right veer off. Move left laterally. Move right laterally. Pop up. Rapid descent. Fire 20-mm by pilot.
Target type	Fixed 7.5 X 7.5 ft (2.28 X 2.28 m). Moving 7.5 X 15 ft (2.28 X 4.56 m). Speeds up to 30 mph (48 kph). Stationary tanks and trucks.

The results of the missile firings were as follows:

a. Eighteen hits on stationary targets.

b. Five hits on moving targets (30 mph (48 kph)).

c. Two misses on stationary targets.

d. One miss on a moving target.

The test results are plotted on the target face depicted in figure 3. A summary of the detailed accuracy analysis is presented in table II. The statistical extrapolation was used to predict the performance of the entire population of TOW missiles based on a small sample of test results. The results are presented with a tolerance and confidence level to relate their probability of being correct. The results of these firings indicate that the TOW missile when fired from the AH-1T helicopter can reasonably be expected to hit any target which is 2 ft (.6 m) or larger in diameter, moving at speeds of less than 30 mph (48 kph), and within the maximum range of the guidance wires.

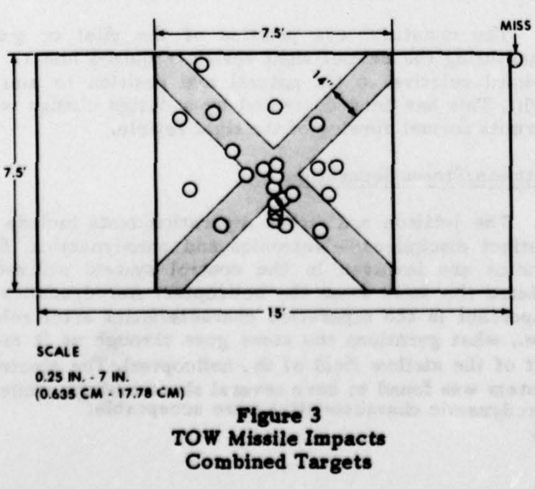


Figure 3
TOW Missile Impacts
Combined Targets

Table II
TOW Missile Accuracy Summary

Target		Test Results	Statistical Extrapolation for Entire Population	
		CEP$^{(1)}$ cm	CEP$^{(1)}$ cm	Confidence Level
Stationary	7.5 X 7.5 ft (2.28 X 2.28 m)	40.6	50.7 ±20%	90%
Moving 30 mph (48 kph) perpendicular to helicopter's flight path	7.5 X 15 ft 2.28 X 4.57 m)	51.8	33.1 ±40%	90%
Composite (All firings)		51.8	50.6 ±17%	90%

NOTE: (1) CEP (Circular Error Probable) - The size of a circle drawn about the *target which contains 50% of the impacts.*

Accuracy data were analyzed in terms of a fixed distance from the target center, since the TOW missile is being guided along the LOS by its associated electronics. The predominant factor in missile accuracy was the ability of the gunner to track the target. Any parameter which reduced his performance resulted in a significant reduction in missile accuracy. The most significant single factor which affected the abilities of the gunner was the pilot's performance. If the pilot did not maintain a somewhat stable airframe, the gunner's ability to track the target was poor. The most predominant factor which affected the pilot was the meteorological conditions (i.e., gusty winds or thermal convection), particularly in aircraft yaw. Airframe and system deficiencies also inhibited the gunner's ability, as documented during two of the firings which missed their targets. On these occasions, the pilot fired the 20-mm flexible turret at a target 90 deg to the right of the aircraft while the TOW missile was in flight. The recoil from the gunfiring created airframe vibrations which caused the gunner's cross hairs to stray from the target. In investigating the source and intensity of these vibrations, it was found that the Stability and Control Augmentation System (SCAS) gunfiring compensator was not designed for the firing rates of the installed 20-mm turret and that the turret firing rate did not meet the specification requirements. The SCAS compensator circuit senses the azimuth and elevation position of the gun turret. When the turret is fired, a step input is fed into the SCAS pitch, roll, and yaw channels to compensate for the recoil of the gun. However, since the actual gunfiring rate was low and the compensation circuits were those designed for the AH-1J, improper compensation was provided and aircraft vibrations were excessive. In the production AH-1T helicopter, the contractor will add a three-position gain switch with which the pilot can increase or decrease the amount of compensation, depending on aircraft feel during firing.

The only other missile which missed the target was fired out of range. The maximum range of the TOW missiles utilized during the test program was 3,000 m, when fired from a hover. As aircraft speed is increased, the range capability of the missile increases. This missile which missed the target was fired at 3,212 m and 100 kt airspeed. For the launch condition specified, the maximum missile range is 3,206 m. Hence, the missile (which had previously been right on target) ran out of wire, lost guidance, and missed the target by approximately 1 m.

The maintenance aspects of the TMS were evaluated continually as maintenance was performed and many positive results, along with one major deficiency, were documented. There were no aborted missions due to armament system failures, and only two components of the TMS were replaced during the entire test program, a bearing in the TSU gimbal and an elevation drive module in the Stability Control Amplifier. The bearing was replaced because of excessive lubricant leakage which caused droplets on a lens in the TSU optics; this was a nuisance but did not render the system unusable. The elevation drive module failed during a ground functional and boresight test and, therefore, did not result in an aborted mission.

In view of the shipboard environment of the AH-1T, the boresighting maintenance task was unsatisfactory. Boresighting the TMS required setting up a boresight target 500 in. (12.7 m) in front of the helicopter armament datum line and aligning the roll angle of the TOW Missile Launcher (TML) to the TSU using a gunner's quadrant (bubble level). In the shipboard environment, the availability of 500 in. (12.7 m) for target placement will be extremely limited. Additionally, on a rolling or pitching ship, a gunner's quadrant is unusable. Since the TMS must be reboresighted each time a TML is installed or aircraft reconfigured to a TOW mission and when a TSU or articulated pylon is changed, these procedures are unacceptable. This deficiency has been addressed by the contractor and a new boresight fixture, which eliminates the need for 500 in. (12.7 m) of clear area and bubble level, has been designed.

Test and evaluation programs are established to identify deficiencies in a controlled environment where they can be documented. Obviously, unexpected occurrences are not desirable and detailed planning is intended to eliminate or at least minimize these situations. However, one surprise occurred during the test program which documented a system deficiency. During a missile firing, the gunner did not release the trigger-on action bar after the target was destroyed, and the TMS automatically sequenced itself to the next missile and fired it. The subsequent investigation documented the lack of any firing pulse interruption in the TMS automatic mode. As a result, emphasis has been placed by all pilots, gunners, and instructors on this operational mode of the TMS.

Helmet Sight Subsystem

The concept of a helmet sight is new to the U.S. Marine Corps attack helicopters. Its primary purpose is to decrease the target acquisition time for the TMS, with a secondary function to act as a flexible sight for the 20-mm flexible turret. The system utilized consists of a mechanical linkage which attaches from the airframe, through a set of electronic resolvers, to a bracket mounted on the pilot/gunner's helmets, as shown in figure 4. The LOS of the helmet is transmitted from the resolvers through an electronic interface assembly to both the TMS and 20-mm flexible turret.

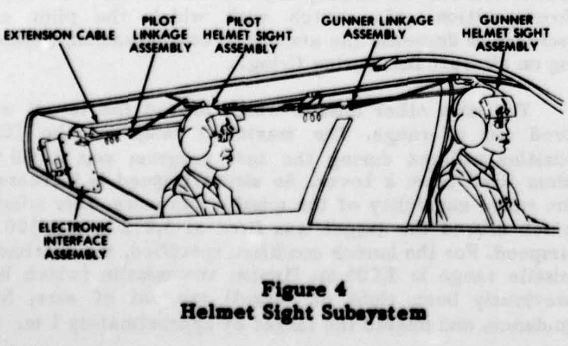


Figure 4
Helmet Sight Subsystem

Ground and flight functional tests indicated all of the HSS controls and indicators functioned as advertised. The HSS was utilized in all modes by both pilot and gunner with the TMS and 20-mm flexible turret. Its prime purpose of providing rapid target acquisition was completed adequately, while its use with the 20-mm turret was a significant improvement over the pantographic sight in the current AH-1J/T. The specific benefits of the helmet sight are as follows:

a. Hands-free operation of the sight allows the gunner to manipulate charts and perform other tasks involved with navigation of the aircraft. This feature is especially important during low-level flight when navigation is a continuous operation. Also, the gunner/copilot is available for emergency operation of the aircraft if the pilot is incapacitated.

b. The dual cockpit installation allows either the pilot or gunner to fire the turret in the flexible mode, reducing response time to enemy action and allowing more flexibility in the task distribution between the two crew members.

c. The turret can be more easily aimed at the extremes of its firing envelope.

During the test program, two deficiencies were identified which required correction: the inability to boresight the helmet sight in the shipboard environment and the unnatural eye position of the pilot or gunner when using the helmet sight reticle. The boresight problem is basically the same as that found with the TMS. A bubble level was required to align the rail assembly which attaches to the mechanical linkage from the helmet to the airframe. Additionally, three simultaneous targets located 500 in. (12.7 m) in front of and beside of the aircraft is required. The contractor has redesigned the electronic interface system to add a trim control box for each helmet sight and integrated the helmet sight boresighting into the same new fixture they will utilize with the TMS.

The unnatural eye position of the pilot or gunner when using the helmet sight reticle required him to look upward relative to his natural eye position to aim the sight. This has been corrected by a design change which permits normal viewing of the sight reticle.

Jettison/Stores Separation

The jettison and stores separation tests include two distinct disciplines: electronics and aerodynamics. Electronics are involved in the control system utilized to release the store from the helicopter. Aerodynamics are important in the separation characteristics after release (i.e., what gyrations the store goes through as it moves out of the airflow field of the helicopter). The electronic system was found to have several shortcomings, while the aerodynamic characteristics were acceptable.

The jettison sequencing varies depending on which stores are loaded on the different aircraft wing stations. As a result, a time delay is required after the jettison button is depressed before a store is released. However, delay times exceeding 2 sec were documented during the test program. This delay is excessive for an emergency situation where the performance increase from immediate weight reduction may be important, as in the low-level nap-of-the-earth environment.

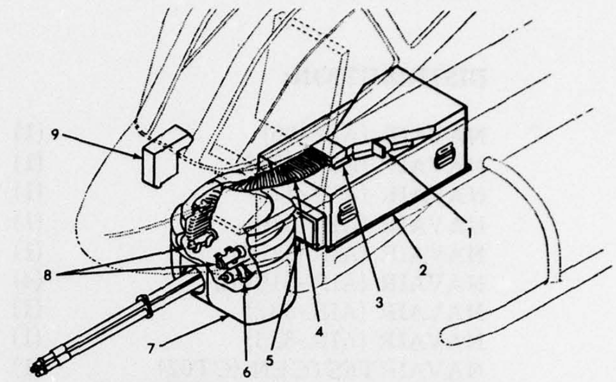
To provide guaranteed capture and guidance of the TOW missile over an acceptable flight envelope, the missile launcher is articulated. This is accomplished by installing the articulated bomb rack, which was originally designed for the U.S. Army AH-1Q helicopter on wing stations 1 and 4. During the test program, it was found that the AH-1Q articulated bomb rack was not compatible with the electrical jettison system on the AH-1T. While the bomb rack incorporated jettison squibs, it also contained current limiting resistors. However, the basic AH-1T electrical jettison system includes a current limiting resistor; having both in the system decrease the current to the jettison squibs, thereby reducing their probability of detonation. In production aircraft, the resistor in the airframe system will be removed.

The aerodynamic aspects of the jettison and stores separation were excellent. Photographic data for the jettison profiles indicated acceptable clearances between the aircraft and authorized stores during separation. No airframe or store-to-store contacts were recorded. During forward firing, missile separation characteristics were excellent. Wire entanglement did not occur nor did launch motor debris impact the airframe. It was noted that the blast from the missile launch motor created a shock wave which had significant effect on the aircraft tail boom. This was in the form of a traveling wave which moved down the tail boom creating a high pressure front and causing the helicopter sheet metal skin to flex. It is envisioned that repeated launch motor blasts may have long-term detrimental effects on the life of the AH-1T tail boom.

20-mm Flexible Turret

The turret on the TOW missile-configured AH-1T helicopter is virtually identical to that on the AH-1J helicopter except for rate of fire, elevation limits (the larger rotor reduced the upper elevation to keep rounds from passing through the tip path plane), sights, and recoil system. The turret system provides for the positioning, ammunition feeding, and firing of the M-197 20-mm automatic gun. The system consists of a turret assembly, turret control assembly, recoil adapters, gun drive assembly, gun control assembly, feed chute, booster assembly, ammunition box, and pressure transducer, as shown in figure 5. The system carries 750 rounds of continuously belted ammunition and fires at a nominal rate of 650 rounds/minute through an azimuth of ± 110 deg. Elevation limits are 50 deg down and 11 deg up directly ahead of the aircraft, increasing to 14 deg up on either side. As a result of the similarities between this system and that on other aircraft only qualitative tests were conducted. The primary emphasis of these tests was to ensure proper system integration and function of controls.

The test results indicated that the system had no major deficiencies and performed as advertised, except for the gunfiring rate and SCAS compensation discussed



1. PRESSURE TRANSDUCER
2. AMMUNITION BOX
3. BOOSTER ASSEMBLY
4. FEED CHUTE
5. GUN CONTROL ASSEMBLY
6. GUN DRIVE ASSEMBLY
7. TURRET ASSEMBLY
8. GUN RECOIL ADAPTERS
9. TURRET CONTROL ASSEMBLY

Figure 5
20-mm Flexible Turret Components

previously. Integration with the telescopic sight from the TMS and helmet sight was successful and accuracy results achieved with existing fire control compensation were better than those obtained during previous testing. The impact of not having a completely compensated fire control system was documented.

On the two occasions when the 20-mm gun was fired while the TOW missile was in flight, the guidance wires for the TOW missile were severed. Documentation from the onboard cameras indicated that the muzzle blast from the 20-mm gun caused the wire breakage. On the first occasion, the missile had impacted the target when the wire was severed and there was no effect on missile performance. In the second instance, only one wire was broken and the missile continued to guide properly to the target. Subsequent discussions with the contractor indicated that missile guidance on one wire had been documented previously, but that the probability of proper guidance with one wire is small. As a result, it was recommended that the following note be included in the AH-1T operator's manual:

"Firing the 20-mm gun to the side of the helicopter from which a TOW missile has been launched may sever the guidance wires and degrade the accuracy of the TOW missile.

Summary and Conclusions

The TOW missile-configured AH-1T demonstrated the potential to accomplish the close-in fire support and anti-armor/heavy-point target attack tasks of the U.S. Marine Corps Attack Helicopter mission. During this test program, an early definition of possible fleet problems and assistance in their early resolution were obtained.

In the design and adaptation of one weapon system to a new aircraft or mission requirement, a thorough review of all aspects of the new environment, including climatic, physical space, and facilities, along with personnel staffing and training, must be made. Additionally, a thorough design, analysis, and proof testing program must be defined to ensure proper integration of the final product. If these phases of the program are short changed, it will be noticeably apparent in the operational system.